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A PRELIMINARY EVALUATION OF LAND USE MAPPING AND CHANGE DETECTION CAPABILITIES USING AN ERTS IMAGE COVERING A PORTION OF THE CARETS REGION

by

Katherine A. Fitzpatrick
and
Harry F. Lins, Jr.
U.S. Geological Survey
Geographic Applications Program
Washington, D.C.

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A preliminary study on the capabilities of ERTS data in land use mapping and change detection was carried out in the area around Frederick County, Maryland, which lies in the northwest corner of the Central Atlantic Regional Ecological Test Site (CARETS). The investigation has revealed that Level I (of the Anderson classification system) land use mapping can be performed and that, in some cases, land undergoing change can be identified. Results to date suggest that more work should be done in areas where land use changes are known to exist, in order to establish some form of base for recognizing the spectral signatures indicative of change areas.

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Katherine A. Fitzpatrick and Harry F. Lins, Jr.

Geographic Applications Program
U.S. Geological Survey
Washington, D.C. 20242

ABSTRACT

A preliminary study on the capabilities of ERTS data in land use mapping and change detection was carried out in the area around Frederick County, Maryland, which lies in the northwest corner of the Central Atlantic Regional Ecological Test Site (CARETS). The investigation has revealed that Level I (of the Anderson classification system) land use mapping can be performed and that, in some cases, land undergoing change can be identified. Results to date suggest that more work should be done in areas where land use changes are known to exist, in order to establish some form of base for recognizing the spectral signatures indicative of change areas.

INTRODUCTION

Cloud-free ERTS imagery covering a portion of the Central Atlantic Regional Ecological Test Site (CARETS) was acquired September 6, on the spacecraft's ninth pass over the area. An attempt to evaluate the usefulness of ERTS imagery in the mapping of land use and detection of land use change was made using the first of this data received that covered a portion of the CARETS area. The frame studied in this report, designated E-1045-15243, covered an area from northern Montgomery County, Maryland, in the southeast to the town of DuBois, Pennsylvania, in the northwest.

REGIONAL DESCRIPTION

Morphologically, the area covered by the image is dominated by the folded ridges of the Appalachians. In the color-infrared composite the uncut forest cover along the ridges stands out vividly in contrast to the cleared agricultural land in the surrounding valleys. Physiographically, four major provinces, the Allegheny Plateau, Ridge and Valley Province, Great Valley and the Piedmont stand out, each exhibiting its own unique geographic characteristics (Figure 1).

Original photography may be purchased from:
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

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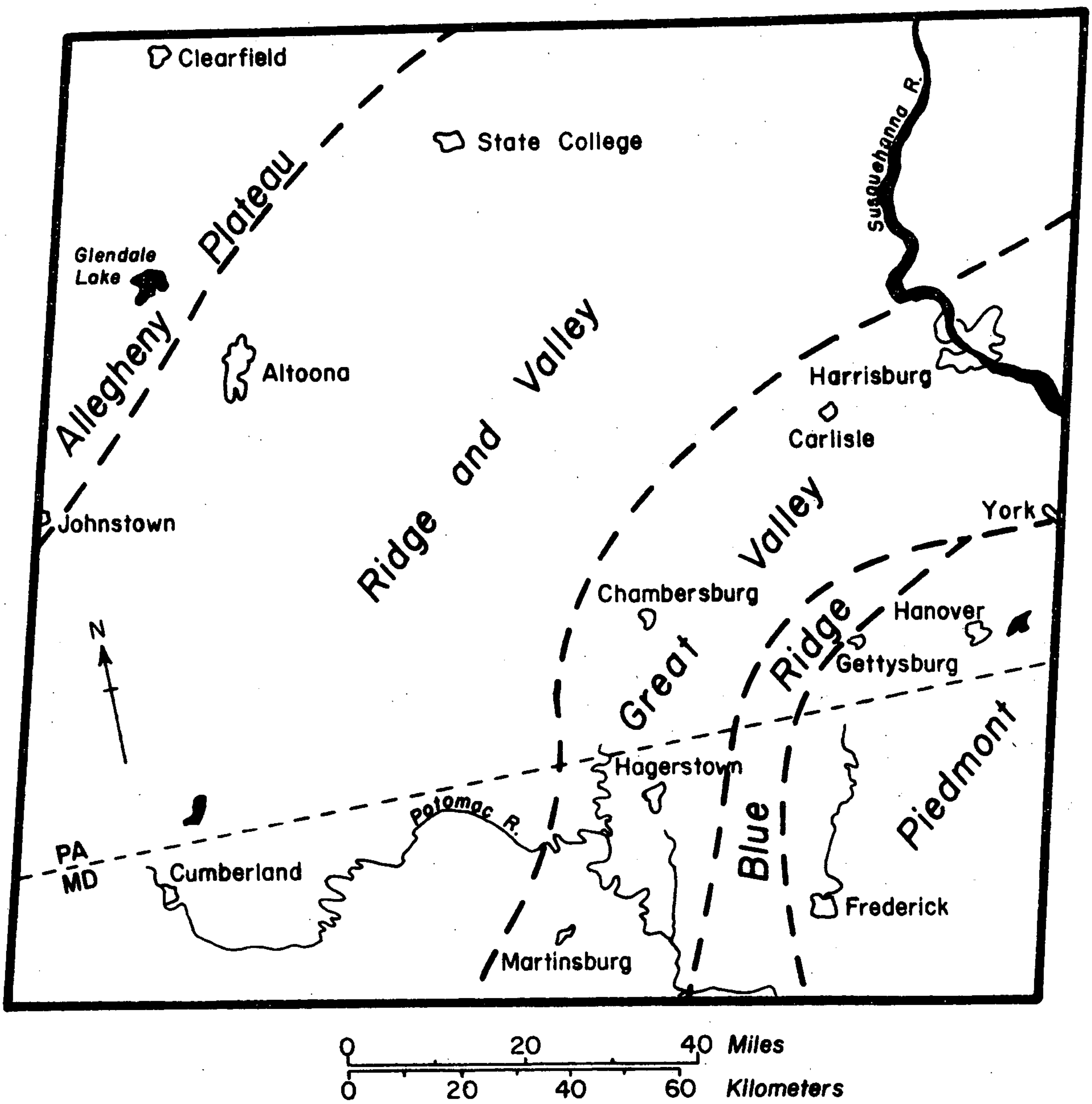

Figure 1. Map showing physiographic regions and urbanized areas as interpreted from ERTS frame E-1045-15243.

The Allegheny Plateau, visible in the northwest section of the frame, appears dissected by several small meandering streams and broken into a patchwork of field and forest patterns. Because of the fragmented pattern of the landscape and the large number of streams appearing in the infrared band, this area is interpreted to have considerable relief, although it does not display the ridge formations evident to the east in the next major region, the Ridge and Valley Province.

The forested land appears dark gray on the black-and-white print of the Multi-Spectral Scanner (MSS) 4 (spectral green) and MSS 5 (spectral red) images in contrast to the cleared land. The forest covered ridges therefore stand out boldly against the light gray tones of the agricultural valleys, enhancing the impression of greater relief. The tone of the forest pattern has another advantage in that forested features on the satellite imagery can be easily compared to the forest overprint on 1:250,000 scale topographic maps.

Immediately to the east of this area lies the Great Valley. It is a region of low relief and is distinguished as a completely agricultural area. Except for some evidence of solid crown forest along the Conococheague River the valley is all cropland.

Finally the Piedmont, to the east of the Blue Ridge, lies dissected by small forest patterns standing where the soil is probably thin or less fertile. Even so, the forest patterns of this area are distinct from those of the Allegheny Plateau in that they are more scattered and do not partition the area quite as much. This characteristic form alone, as recorded on the imagery, shows that the Piedmont is a less rugged and more rolling countryside than the Allegheny Plateau.

DATA ANALYSIS

Feature Recognition Using Multi-Band Analysis

For the purposes of land use mapping the advantages of individual spectral bands in black-and-white are limited, color infrared being, by far, the optimum spectral arrangement. However, MSS 5 (red) proved to be of value in the recognition of certain cultural features (Figure 2). For example, the cities of Altoona, Chambersburg, Harrisburg, Hagerstown, Frederick, and Cumberland are all visible as faint gray tones. Also, many of the connecting highways such as I-70, U.S. Rt. 40, and U.S. Rt. 15 to Frederick are clearly distinguishable. By following transportation routes such as these, it is possible to locate other urban areas not immediately obvious. By using this method, it was possible to locate Martinsburg, W. Va.,

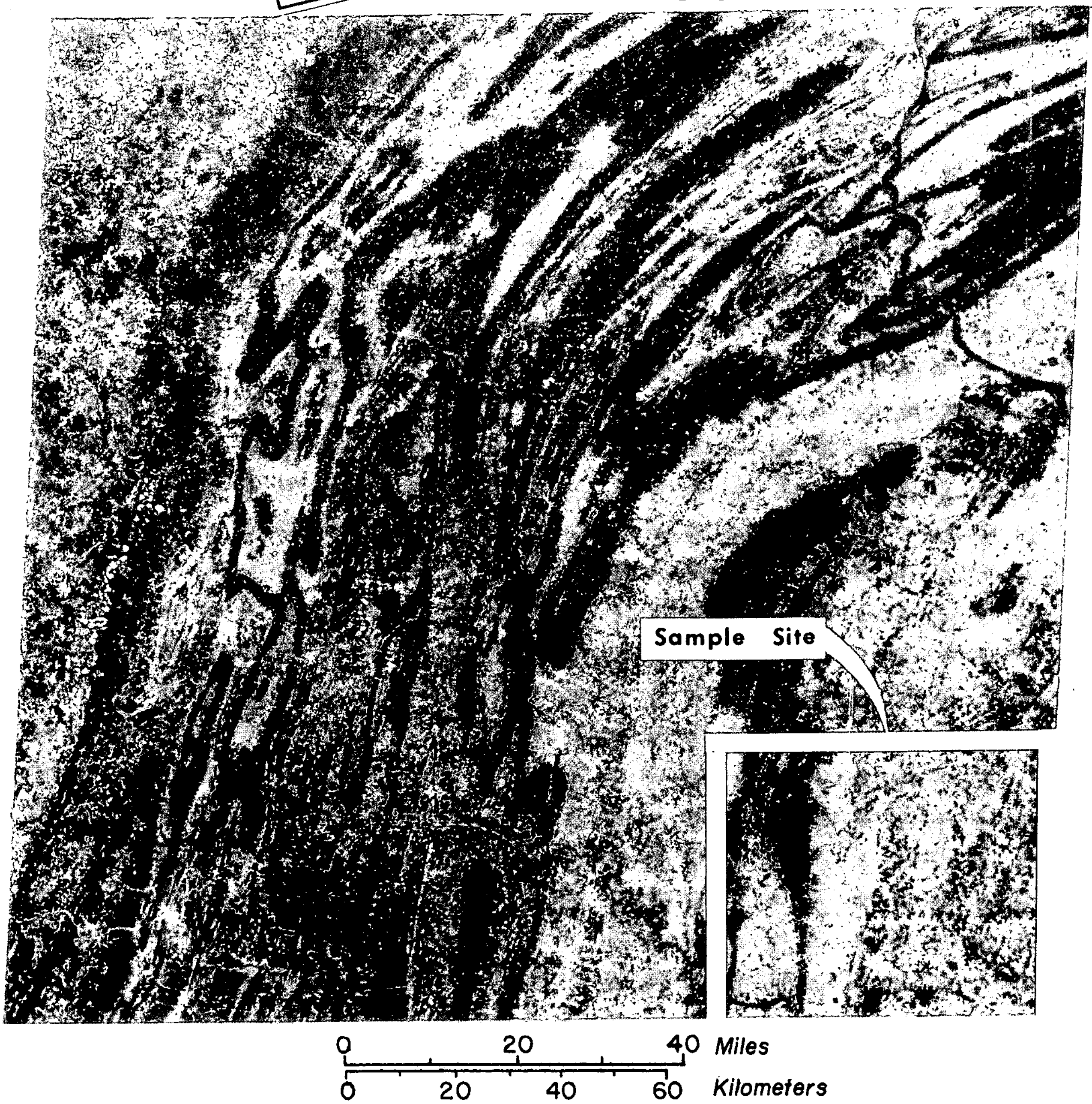

Figure 2. Photograph of ERTS frame E-1045-15243-5 showing the sample site examined in this study. This image is the spectral red band (MSS 5) and has been enlarged 2.8X to a scale of approximately 1:1,180,000.

Hanover and Gettysburg, Pa., and even such small settlements as New Market, Md. About the only other man-influenced features that stand out are some quarries and the airfield at Martinsburg which for some, as yet unknown, reason is the only airport giving a bright enough return to be visible on the image.

The two infrared bands, MSS 6 and MSS 7, are useful for delineating water areas. Both the Susquehanna and Potomac Rivers are sharply defined and because of the near total absorption of electromagnetic radiation in the near infrared band (700 - 1,100 nanometers) of MSS 6 and 7 combined the black tone of the water dominates the image. However, due to the smallness of scale of the original imagery (1:3,300,000), smaller rivers such as the Monocacy are barely visible. MSS 7 (800 - 1,100 nm) was the sharpest of the two IR bands, not only for delimiting water features. but also for enhancing urban areas and ridge lines.

Sample Site

Frederick County, Maryland, and vicinity was chosen as a sample site for conducting initial ERTS studies. It was selected because the entire county, which is part of CARETS, was visible on one ERTS frame (actually the county occupies only a small section in the southeast corner of the frame). Also this area was close enough to Washington, D.C., and small enough in size to permit rapid field checking. Frederick County lies in both the Blue Ridge and Piedmont Provinces and in a quick view of the ERTS image of this area such major features as the Catoctin and South Mountains, the Middletown Valley, Sugarloaf Mountain, the city of Frederick and a generalized agricultural land use pattern are easily noticed. As this was suspected of being a rather dynamic area within the CARETS region, it was decided to attempt both a Level I land use map of the entire county using ERTS imagery and a "quick look change detection" experiment.

Land Use Interpretation and Mapping

The interpretation and mapping of land use was accomplished using the latest classification system devised by the Inter-Agency Steering Committee on Land Use Information and Classification (Anderson, et al, 1972) seen in Figure 3. The Level I interpretation was performed using two optical projection methods. The first was simple optical enlarging using the Richardson Film Projection Viewer with the MSS 5 image and the second was color additive viewing using the I^2S viewer with all four bands of the MSS.

The MSS 5 image was enlarged ten times on the film projection viewer to a scale of approximately 1:330,000. Stable-base frosted Herculine

A LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Level I	Level II	Level I (Digit)	Level II (Digit)
Urban & Built-up		01	
	Residential		01
	Commercial & Services		02
	Industrial		03
	Extractive		04
	Major Transport Routes & Areas		05
	Institutional		06
	Strip & Clustered Settlement		07
	Mixed		08
	Open & Other		09
Agricultural		02	
	Cropland & Pasture		01
	Orchards, Groves, Bush Fruits, Vineyards & Horticultural Areas		02
	Feeding Operations		03
	Other		04
Rangeland		03	
	Grass		01
	Savannas (Palmetto Prairies)		02
	Chaparral		03
	Desert Shrub		04
Forestland		04	
	Deciduous		01
	Evergreen (Coniferous & Others)		02
	Mixed		03
Water		05	
	Streams & Waterways		01
	Lakes		02
	Reservoirs		03
	Bays & Estuaries		04
	Other		05
Non-Forested Wetland		06	
	Vegetated		01
	Bare		02
Barren Land		07	
	Salt Flats		01
	Sand (other than beaches)		02
	Bare Exposed Rock		03
	Beaches		04
	Other		05
Tundra		08	
	Tundra		01
Permanent Snow & Ice Fields		09	
	Permanent Snow & Ice Fields		01

Figure 3. Land use classification system devised by the Inter-Agency Steering Committee on Land Use Information and Classification. (Anderson, et al., 1972)

drafting film was placed on the viewer's screen and the various land use patterns were outlined on this medium. MSS 5 was selected for the interpretation because it had the highest contrast ratio of the four bands. However, no single band of MSS imagery was sufficient in itself for land use analysis at this scale and supplemental data were important. The Baltimore 1:250,000 scale USGS Topographic Map was a helpful aid in deciding whether or not numerous faint patterns on the imagery were towns (Figure 4). Since the MSS image used was not geometrically rectified, the land use map produced from it is primarily for identification and illustrative purposes only, and cannot effectively be used for mensuration.

The actual interpretation took longer than expected, two man-days for an area of approximately 1,500 square miles, because of difficulties in using an overlay on the film projection viewer screen. For example, once the image was in focus on the screen, it was still difficult to trace some of the minimum size areas onto the frosted acetate because the image appeared blurred close-up. Another problem, resulting from the thickness of the frosted viewing screen glass ($\sim\frac{1}{4}$ inch), was that the image as viewed on the acetate would shift in position as much as 5 mm when even a slight change in the angle of viewing was made. Interpreting on acetate over a frosted glass screen, on which an image has been projected, is extremely difficult on the eyes, which frequently will not both focus on the same layer. That is to say, one eye may focus on the image projected on the frosted glass while the other eye focuses on the image seen on the acetate overlay. For this reason it is recommended that prolonged, continuous viewing of imagery on such a viewer not be attempted. A more preferable method would be to interpret at short intervals (about 30 minutes) with ten to twenty minute work periods in-between devoted to tasks less strenous on the eyes.

The most useful interpretation aid available to us in this study was the I^2S Additive Color Viewer. By using this instrument it was possible to distinguish features such as roads and towns that otherwise faded into the background. By varying the filters and light intensities of each spectral band it was possible to tone down certain signatures such as cropland and forests and enhance other features such as urban areas. (An analysis of the optimum film/filter combinations for depicting specific land uses on the I^2S viewer follows.) Verification of these urban areas using the topographic map was then necessary before identifying them as such on the land use map.

Although no land use overlay was made on the I^2S viewer, because of the small size and scale of the projected image ($\sim$1:1,269,000), each Level I land use category could be separately enhanced as an aid in the interpretation of a single spectral band at the 1:330,000 enlargement. At this

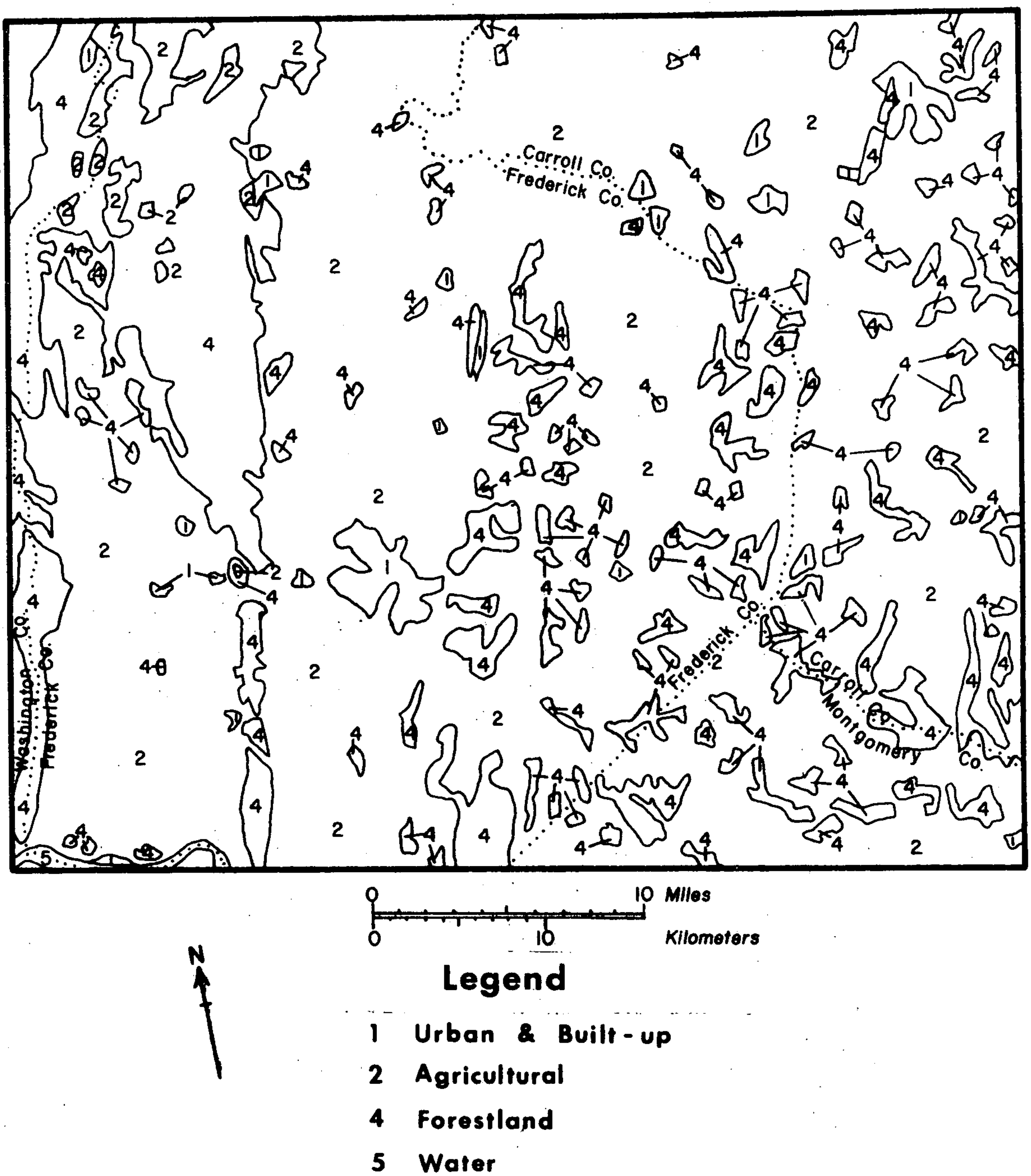

Figure 4. Land use map of a portion of ERTS frame E-1045015243.

scale the size of the smallest map compilation unit (a square 2 mm on a side) was approximately 2 hectares. The following discussion describes the film/filter/light intensity combinations which were most beneficial for interpretation of individual land uses in this particular study.

Urban areas were best identified with the following configurations:

Sensor	Filter	Illumination Setting
MSS 4	Blue	7
MSS 5	Green	7
MSS 6	Red	6
MSS 7	Red	5

Sensor	Filter	Illumination Setting
MSS 4	Green	7
MSS 7	Red	6.5

By toning down the MSS 5 and MSS 6 bands, fields with less IR reflection blended into the general reddish background. Cleared areas, roads, extractive operations and urban areas stand out more vividly. Variations in the intensity settings of the infrared bands produced no increase in the ability to locate urban areas. Illumination increases in the MSS 6 and MSS 7 bands flooded the image with red, making other color patterns too difficult to see. Illumination decreases in either one of the IR bands produced no observable beneficial change and in both bands simultaneously caused a marked loss in detail, due to the removal of the infrared enhancement of vegetation.

Transportation patterns stand out best with:

Sensor	Filter	Illumination Setting
MSS 4	Blue	5.5
MSS 5	None	4.5

The infrared bands wash out transport routes completely.

Water bodies, on the other hand, are most enchanced in the infrared bands, particularly MSS 7. It was found that for optimum viewing, though, it was best to use a green filter and one or two other spectral bands to reduce the harsh visual effect of the single color image. Such as,

Sensor	Filter	Illumination Setting
MSS 4	Blue	7
MSS 6	None	5
MSS 7	Green	5.5

Forested areas showed up quite well on the MSS 5 image by itself, but these same areas showed up even better on the color infrared composite produced as follows:

Sensor	Filter	Illumination Setting
MSS 4	Blue	7.5
MSS 5	Green	6.5
MSS 6	Red	6
MSS 7	Red	4.5

Agricultural land is also most easily recognized using a color infrared composite image made with the configuration:

Sensor	Filter	Illumination Setting
MSS 4	Blue	7
MSS 5	Green	7
MSS 6	Red	6
MSS 7	Red	6

FIELD OBSERVATIONS/CHANGE DETECTION

In addition to the Level I land use categories there were a number of bright spots which stood out on the imagery. A few of these spots, about 25 in the Frederick County area, were selected as points of field check because, in this geographical area, it was expected that such a higher albedo was indicative of cleared fields or new cultural features. It was felt that if areas of change could be immediately identified as being different from cleared cropland, ERTS imagery, because of its synoptic characteristic, would be an advantageous tool. Before the field checking could begin, it was necessary to locate the sample sites more precisely. The area was first outlined on RC-8, 1:120,000 scale color infrared photography, from NASA Aircraft Mission 144. This "underflight-type photography" was essential at this stage in the research. The sites were then charted on the Baltimore, 1:250,000 topographic sheet.

All of the sample sites stood out as small bright spots on the I^2S composite image. Some didn't appear to be significantly different from the agricultural land with the exception that they were much lighter in tone. It was anticipated that these sites would be cleared cropland. Other sites, which rendered a faint blue signature of the I^2S composite, were expected to be areas of urban development.

A total of 19 sample sites were checked and of these 12 turned out to be fields which apparently had been either harvested or sown at the time of image acquisition. Some areas, expected to be undergoing urban development, turned out to be already established urban land use, not experiencing construction. For example, at Point of Rocks, Md., a large industrial complex, several acres in extent, appeared to be a large cleared area on the ERTS image, possibly exhibiting some new development. In the field, however, no construction was found, only several large, highly reflective flat-roofed buildings.

Two of the sites field checked were correctly interpreted as areas under construction. One, a shopping center and apartment complex under construction, just west of Frederick along Route 40; and two, highway construction near New Market. Unlike the areas of agriculture transition these areas were along major transportation routes and did show more spectral reflectance in the MSS 4 suggesting some form of urban land use.

It is, therefore, possible to say that the signatures from both cleared land and paved surfaces, as projected by a combination of spectral bands and filters, (MSS 4 through blue and MSS 5 through green) on the I^2S viewer may in fact be indicative of land use change. In some cases, such as the industrial complex around Point of Rocks, these composited signatures may exist in spite of the fact that no construction is occurring. This points to the fact that some form of field work would be necessary to segregate certain land use categories.

Large paved areas surrounded by agricultural land, such as the electric power substation and the East Alco Aluminum Plant both in the Frederick Valley between Point of Rocks and Mountville, were mistaken as being areas possibly in urban development. These particular sites were valuable though, in proving ERTS capable of discriminating signatures from areas less than two hectares. Several quarries were visible on the ERTS frame, although, had these points not been located on the RC-8 photography and the topographic map, positive identification of them as being quarries would not have been possible.

The field work provided good indications that areas undergoing change (both between and within land use categories) can be identified from ERTS imagery once an initial signature or composited signature has been established.

CONCLUSIONS AND RECOMMENDATIONS

From the work completed to date it would appear that ERTS imagery is not only useful for mapping land use at Level I and also certain categories in Level II, but capable of monitoring agricultural changes and locating areas of construction, when such land uses approach an area of approximately two hectares. However, small increments in the size of an urban area or major industrial complex may be most difficult to identify since such small changes don't stand out well against a homogeneous background. Admittedly, ERTS was not intended to provide imagery for use in such highly detailed work, but this study attempted to push the data to its limits of resolution.

For future studies the following image formats are submitted as probably being the most valuable in land use mapping and change detection: 1) a 70 mm transparency of MSS 4, 5, 6, 7 and of the color infrared composite, and 2) a 9 x 9 transparency of MSS 5 and of the color infrared composite.

NEXT PHASES OF THE STUDY

Now that the 1970 land use data base (from high-altitude aircraft photography) is nearly completed for the entire CARETS area the next phase in the project is to begin work on the 1972 update. This update will provide the land use information needed to make change assessments for the environmental and planning needs, and to provide an ERTS-contemporaneous data base for quantitative assessment of land use data derived from ERTS. The land use data will then be converted to digital form for computer retrieval by individual land use category or mixes of categories. Finally, the ERTS analysis will be extended to the remainder of the CARETS region for systematic comparison with the aircraft data base and standardized land use classification. Unlike the present "quick-look" study, the final analyses will map ERTS data on a rectified base for quantitative data reduction.

REFERENCE

Anderson, J. R.; E. E. Hardy; and J. T. Roach; 1972: A land-use classification system for use with remote sensor data; Geological Survey Circular 671, Washington, D.C.

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